STATE OF VERMONT
PUBLIC SERVICE BOARD

Docket No. 6860

Petitions of Vermont Electric Power Company, Inc. ("VELCO") and Green Mountain Power Corporation ("GMP") for a Certificate of Public Good authorizing VELCO to construct the so-called Northwest Vermont Reliability Project, said project to include: (1) upgrades at 12 existing VELCO and GMP substations located in Charlotte, Essex, Hartford, New Haven, North Ferrisburg, Poultney, Shelburne, South Burlington, Vergennes, West Rutland, Williamstown, and Williston, Vermont; (2) the construction of a new 345 kV transmission line from West Rutland to New Haven; (3) the construction of a 115 kV transmission line to replace a 34.5 kV and 46 kV transmission line from New Haven to South Burlington; and (4) the reconductoring of a 115 kV transmission line from Williamstown, to Barre, Vermont

SUPPLEMENTAL DIRECT TESTIMONY OF
GEORGE E. SMITH & W. STEVEN LITKOVITZ
ON BEHALF OF THE
VERMONT DEPARTMENT OF PUBLIC SERVICE

May 20, 2004

Summary: Mr. Smith's and Mr. Litkovitz's testimony: 1) addresses the effects of VELCO's proposed changes to the NRP, as provided in VELCO's supplemental filing dated February 6, 2004, with respect to the overall goals, reliability, and cost of the project; 2) considers the benefits and costs of VELCO's proposal to use a wider range of structure heights; 3) comments on the feasibility of a proposal by Department witness David Raphael regarding the routing of the proposed 115 kV line in the vicinity of the Waldorf school in Charlotte; 4) considers VELCO's estimates of certain undergrounding costs; and 5) addresses interests raised by the Board with respect to the use of alternate conductor types.

Supplemental Direct Testimony
of
George E. Smith & W. Steven Litkovitz

Identification of Witness and Qualifications, Mr. Smith

Q. Please state your name and position.

A. My name is George E. Smith. I am a professional engineer and consultant to the Vermont Department of Public Service (Department).

Q. Are you the same George E. Smith that previously submitted testimony in this proceeding?

A. Yes, I am.

Identification of Witness and Qualifications, Mr. Litkovitz

Q. Please state your name and position.

A. My name is W. Steven Litkovitz. I am an Electrical Engineer for the Vermont Department of Public Service.

Q. Please state the primary duties of your position.

A. My primary responsibility is to review the appropriateness of Vermont electric utilities' transmission and distribution plans and operations.

Q. Please state your experience and qualifications.

A. I have held my present position since July 1993. From 1988 to 1993, I held the position of Electrical Engineer for the Massachusetts Department of Public Utilities (MDPU). At the MDPU I was responsible for engineering and financial analysis in numerous electric utility regulatory proceedings. Before working with the MDPU, I taught secondary level Physics and Electricity for two years. Previous to this, I worked as an Electrical Engineer in Training for the Cleveland Electric Illuminating Company and the Boston Edison Company. I received a Bachelor of Science in Engineering degree in Electrical Engineering from the University of Michigan in 1981, a Master of Science degree in Electric Power Systems Engineering from the Ohio State University in 1982, and a Master of Business Administration degree from the Ohio State University in 1984.

Q. Have you testified previously before the Vermont Public Service Board (Board)?

A. Yes. I have provided testimony to the Board in numerous dockets over the past ten years.

Overview

Q. What is the purpose of your testimony?

A. On February 6, 2004, the Vermont Electric Power Company (VELCO) provided supplemental prefiled testimony in this proceeding describing a number of proposed changes to its Northwest Vermont Reliability Project (NRP). The purpose of this testimony is to provide our opinion on how these proposed changes would effect the overall goals, reliability, and cost of the project. We also consider the cost and effects of VELCO's proposal to use a wider range of structure heights in the NRP. We comment on the feasibility of a proposal by Department witness David Raphael regarding the routing of the proposed 115 kV line in the vicinity of the Waldorf school in Charlotte. We provide our view on VELCO's estimates of certain undergrounding costs. Finally, we address interests raised by the Board with respect to the use of alternate conductor types.

Q. Please summarize the conclusions reached in your testimony.

A. A summary follows:

1) VELCO's proposed changes to the NRP have no significant effect on the overall goals of the NRP.
2) VELCO's proposed changes to the NRP have no significant effect on the reliability of the NRP.
3) VELCO's proposed changes to the NRP result in a cost increase to the project of less than 1%.
4) VELCO's proposal to use a wider range of structure heights in the NRP

provides certain benefits. The costs incurred would not be significant.

5) The route proposed by Mr. Raphael for the 115 kV line in the vicinity of the Waldorf school in Charlotte is feasible and would have no adverse effect on the reliability or the cost of this transmission line.

6) VELCO's estimates of certain undergrounding costs are reasonable and are consistent with estimates previously provided by Mr. Smith. We do not support the use of undergrounding in the NRP.

7) Regarding the use of alternate conductor types in the NRP, we do not believe that the use of composite core conductors is warranted due to this technology's lack of maturity and high expected cost. We do believe, however, that the use of aluminum conductor steel supported (ACSS) conductor, which is a conventional, mature technology, should be considered where pole height reductions are desired for aesthetic mitigation.

Effects of VELCO's Proposed Changes on the Goals of the NRP

Q. Do the reroutes, structure height changes, new Vergennes substation, Charlotte substation relocation, and substation redesigns proposed by VELCO in their supplemental testimony effect the overall goals of the proposed NRP?

A. No. Overall, the primary goal of the NRP is to provide reliable transmission service to loads in Northwest Vermont for statewide load levels up to 1200 MW. This service includes assuring the adequacy of: 1) the 115 kV bulk transmission system; 2) supply to the Burlington area, including the Burlington Electric Department and the Green Mountain Power Corporation (GMP) subtransmission system; and 3) supply to local loads served by substations in Vergennes, Ferrisburg, Charlotte and Shelburne. With respect to these goals, the changes proposed by VELCO are minor and would have no significant effect.

Effects of VELCO's Proposed Changes on the Reliability of the NRP

Q. Do the reroutes, structure height changes, new Vergennes substation, Charlotte substation relocation, or the substation redesigns proposed by VELCO in their supplemental testimony affect the reliability of the NRP?

A. With regard to the bulk transmission system, the changes proposed by VELCO would have virtually no impact on the level of reliability expected from the NRP. The only appreciable difference to reliability would be to the loads served by GMP from its Vergennes substation. Specifically, the proposed Vergennes by-pass would likely result in a level of reliability to the Vergennes loads that is somewhat lower than that provided by the NRP as originally proposed.

Q. Please explain the impact of the proposed reroute around Vergennes on the reliability to Vergennes' loads as compared to the reliability that would be expected from the NRP as originally proposed.

A. The NRP as originally proposed would provide 115 kV transmission supplies to the GMP Vergennes substation from two directions. Therefore, in the event of the loss of one of these 115 kV lines, supply would be met by the other 115 kV line with no interruption to customers. However, in the proposed reroute configuration, GMP's Vergennes substation would be supplied radially by a 1.6 mile 34.5 kV line. In the event of a permanent outage[1] of this line, customers served by the Vergennes substation would experience an interruption, most likely on the order of several hours. While this supply to the Vergennes substation, from an electrical perspective, is less desirable than that provided by the NRP as originally proposed, the frequency of permanent outages on this line is expected to be low. According to GMP witness Terry Cecchini, considering GMP's historical experience with permanent outages of subtransmission lines, the expected outage frequency for this 1.6 mile radial supply line would be one event per 12.65 years.

[1]Permanent outages usually result from equipment failure, such as the failure of an insulator or lightning arrester, and require crews to make repairs before service can be restored. Repair times are generally on the order of several hours. Temporary outages, on the other hand, usually result from a momentary event such as a lightning flashover. With temporary outages, the line is reenergized, and service restored, automatically in a matter of seconds.

Q. Are provisions proposed by GMP to mitigate the frequency and duration of permanent outages of this radial supply?

A. Yes. According to GMP witness Terry Cecchini, right of way (ROW) maintenance and pole inspections along this radial 34.5 kV feed to the Vergennes substation would be given special attention, materials typically needed for line repair would be stored at the GMP Vergennes Service Center, and procedures would be developed to make use of the Vergennes diesel generator black start capability. These measures would lower the expected frequency and duration of outages to this line.

Q. How would the reliability from the proposed Vergennes reroute compare to the reliability presently provided to the GMP Vergennes substation?

A. At present, the normal supply to GMP's Vergennes substation is a six-mile long 46 kV subtransmission line originating at the VELCO New Haven substation. A back-up supply is provided by an existing 34.5 kV line originating at the VELCO Queen City substation. As described above, the proposed reroute would supply these loads with a single, 1.6 mile 34.5 kV subtransmission feed. This newly constructed shorter line, having less exposure than the 6 mile 46 kV supply from New Haven, would be expected to have fewer outages. On the down side, when permanent outages do occur, they would likely be longer in duration when compared to the present configuration because the back-up 34.5 kV supply would no longer be available. On balance, together with the mitigation proposed by GMP, we believe that the proposed reroute would provide a higher level of reliability to the Vergennes substation than exists today while at the same time satisfying the desire of the City of Vergennes that a 115 kV line not traverse through the City's river basin area. Further, we note that outages on the 1.6 mile 34.5 kV radial feed to Vergennes would have no impact on the other substations supplied by the 115 kV path from New Haven to Queen City and would have no impact on the overall operation of the bulk transmission system.

Q. Do you believe that the lower reliability that would be provided to GMP's Vergennes loads by the proposed reroute, compared to the reliability that would be available from the NRP as originally proposed, is reasonable?

A. Yes. First, as explained above, the proposed reroute would be expected to result in fewer outages than that expected by the present-day configuration. Second, GMP has made provisions to further enhance the reliability of the 1.6 mile 34.5 kV supply to the Vergennes substation. Third, we observe that while dual transmission supplies to substations are ideal, it is not at all unusual for substations serving load in Vermont to be supplied by radial subtransmission lines. In the case of GMP alone, we are aware of at least 12 substations that are supplied radially. And fourth, even when dual transmission supplies are present, we note several instances within Vermont where such systems are not capable of supplying peak loads following contingencies.

Effects of VELCO's Proposed Changes on the Cost of the NRP

Q. What are the effects of VELCO's proposed changes on the cost of the NRP?

A. Overall, VELCO's proposed changes to the NRP result in an increase to the cost of the project of $1.2 million, excluding the cost of additional land and ROW acquisition. See the response to Information Request DPS5-VELCO-60 attached as Exhibit DPS-GES&WSL-1. The majority of this cost increase results from the requirement for a new substation to provide the 34.5 kV supply to the GMP Vergennes substation. While the cost of land and ROW acquisition is not known at this time, we note that the majority of land and ROW acquisition would occur in Ferrisburg as part of the Vergennes reroute. We do not believe that the land and ROW costs through Ferrisburg would be significantly different from the land and ROW costs that would be required for the originally proposed route through the City of Vergennes. The increase to the cost of the project of $1.2 million is less than 1% of the overall cost of the project.

Effects of VELCO's Proposed Changes to Structure Heights on the NRP

Q. In its supplemental testimony, VELCO proposes to use a wider range of structure heights for the proposed 115 kV and 345 kV lines. Do you believe that this proposal is reasonable?

A. Yes. A wider range of structure heights should allow VELCO to better accommodate a variety of environmental and aesthetic concerns. For example, taller structures can permit longer line spans for the purpose of crossing wetlands. Shorter structure heights can help mitigate aesthetic concerns in a given area.

Q. Would you expect this wider range of structure heights to have a significant impact on the cost of the project?

A. No, any changes in cost due to changes in structure heights should be small.

Charlotte Reroute

Q. Are you aware of the recommendations of Department witness David Raphael on VELCO's proposed reroute in the vicinity of the Waldorf school in Charlotte?

A. Yes. We understand that Mr. Raphael does not agree with VELCO's proposed reroute for this area, and instead proposes that the 115 kV transmission line generally be routed along the railroad corridor, behind the Waldorf school.

Q. In your opinion, is Mr. Raphael's proposal feasible from an engineering perspective?

A. Yes. After reviewing Mr. Raphael's proposal, visiting the site, and discussing the proposal informally with VELCO staff, we believe that the route proposed by Mr. Raphael is feasible and would have no adverse effect on the reliability or the cost of this transmission line.

Underground Construction

Q. In its supplemental testimony, VELCO provides estimates for the costs of underground construction in the Towns of Charlotte and Shelburne. What is your view of these estimates in light of previous estimates performed for Shelburne by Mr. Torben Aabo?

A. VELCO's estimates for the cost of underground transmission in these areas, while higher than those of Mr. Aabo, are reasonable. One major factor accounting for VELCO's higher cost estimates is the cable size assumed. VELCO assumes a conductor size of

3000 kcmil[2] in its estimates while Mr. Aabo assumes a conductor size of 1750 kcmil. This results in a difference of approximately $250,000 per mile for a three-cable system. We agree with VELCO that the 3000 kcmil conductor size would be needed for the purpose of providing the same contingency overload capacity that is provided by the proposed 1272 kcmil overhead line construction. In addition, VELCO's cost estimates include provisions for engineering cost, ROW clearing cost, sales tax on materials, and contingency. After consideration of these factors, we believe that VELCO's estimates, averaging roughly $2.4 million per mile for a three-cable system and $2.9 million per mile for a four-cable system, form a reasonable basis for the cost of undergrounding in these areas. While these estimates are consistent with that provided by Mr. Smith in his direct testimony, it is important to note that these estimates may be understated in that they do not include potential cost adders that could be required following a detailed engineering study. For example, if boring technology were required to minimize wetland or water course impacts or if special considerations were required for construction in railroad ROW, costs for this undergrounding would necessarily increase.

Q. What is your view on a three-cable system versus a four-cable system if undergrounding were required for portions of the proposed 115 kV line?

A. In the case of a three-cable system, failure of one cable can result in an extended circuit outage of up to two weeks (or even longer if sufficient spare parts are not on hand). The NRP, as presently designed, accounts for two extended outages, namely an outage of the Highgate converter and an outage of the PV20 transmission line. Use of a three-cable installation as part of the NRP would introduce a third extended outage scenario, one that was not considered in the proposed design of the NRP. To accommodate a third extended outage, a redesign of the NRP would be required possibly resulting in even further

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[2]kcmil is a measure of the cross sectional area of a conductor and is shorthand for thousands of circular mils. A circular mil is defined as the area of a circle having a diameter of 1 mil or 1/1000th of an inch.

transmission additions. However, installation of a four-cable system on the proposed 115 kV line, in which an installed spare cable could quickly be connected in the place of a failed cable, could lead to circuit restoration times comparable to those of an overhead line. For this reason, we suggest that a four-cable system be considered a minimum configuration for undergrounding any portion of the proposed 115 kV line. Before proceeding with any underground solution, we believe that a detailed engineering study would be required to ensure that adequate reliability and electrical performance would be achieved. This study would include verifying the feasibility of an expedient reconnection process with careful attention given to sheath bonding connections.[3]

Q. How would the reliability of a four-cable system described above compare with the reliability of the proposed overhead design?

A. In the event of a permanent outage, the circuit restoration times for a four-cable system could probably be made to be comparable to that of an overhead line. The performance for temporary outages, however, would be different. For overhead lines, when a temporary outage occurs, for example due to a lightning strike, automatic reclosing of circuit breakers would restore the line to service in a matter of seconds. For cable systems, however, automatic reclosing is usually not permitted. This is to guard against possibly further damaging the cable with high short-circuit currents in the event that the initiating short circuit was caused by a failure in the cable itself.[4] Because of this

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[3]With XLPE cable systems, an outer conductive sheath ensures uniformity of the electric field in the dielectric insulating material, and carries circulating currents, charging currents, and fault currents. The induced circulating currents in the sheaths cause losses and heating of the cable thereby compromising the current carrying capacity of the cable system. A method of transposing the sheath connections at each cable section, referred to as cross bonding, effectively cancels the sheath currents, thus minimizing losses and heating and allowing for the full thermal capability of the cable to be achieved. We note, however, that cross-bonding is not feasible for four-cable systems. An equivalent, though less common, method of bonding known as multiple single-point bonding should be investigated if a four-cable system is considered.

[4]This restriction on reclosing would also apply to hybrid lines, i.e., lines comprised of both overhead and underground sections, due to the fact that the precise location and nature of a short circuit would not immediately be known. Because the short circuit could be within the

restriction on automatic reclosing for cables, an event that would result in the loss of an overhead line for a few seconds would probably result in the loss of a cable section for several hours.

Q. In your opinion, can adequate reliability be achieved using a cable system in the NRP?

A. If a four-cable system is used in portions of the proposed 115 kV line, we believe that adequate reliability can be achieved. However, for the reasons discussed immediately above, such reliability would be less than equivalent to that of an overhead line.[5]

Q. In his direct testimony in this proceeding, Mr. Smith testified that he did not support the use of underground transmission due to the adverse cost, reliability, and environmental impacts of undergrounding. Does the testimony above addressing the reliability of cables change these conclusions?

A. No. While we believe that adequate reliability can be achieved with a four cable system, on condition that a detailed engineering study be required before implementation, the fact remains that the reliability of cables would not be equivalent to that of an overhead line. Moreover, the adverse cost and environmental impacts of underground systems remain. For these reasons, our overall recommendation that undergrounding not be used in the NRP remains unchanged.

Use of Alternate Conductor Types

Q. On March 25, 2004, the Board issued a memorandum in this proceeding requesting the "parties provide an evaluation of the merits and potentials" of aluminum-composite conductors. What is your view of the primary benefits afforded by the use of aluminum-composite conductors?

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underground cable section itself, or be a permanent fault on an overhead section, automatic reclosing would be avoided to eliminate the possibility of damage to the underground section.

[5]We have not considered, and reach no conclusions, regarding the feasibility and reliability of a four-cable system for sections of the proposed 345 kV line.

A. In cases where reconductoring is desired for existing lines using existing structures, aluminum-composite core conductor may provide substantially higher current carrying capacity than can standard aluminum conductor steel reinforced (ACSR) conductor. This increased current carrying capacity may be as much as twofold and is due to the fact that the thermal expansion versus loading, and the associated increase in sag of this conductor type, is substantially less than that of ACSR.

Q. How could the improved performance of aluminum-composite core conductor be applied to new transmission line construction in the proposed NRP?

A. For a given selected ACSR conductor size, use of aluminum-composite core conductor would result in reduced conductor sag. As a result, pole heights could be reduced providing an aesthetic benefit. For a span length on the order of 550 feet, a reduction of structure heights on the order of 4 feet may be achieved.

Q. What composite core conductor types are available?

A. We are aware of two types. One, referred to as ACCC (Aluminum Conductor Composite Core), is being marketed by Composite Technology Corporation. It has a core comprised of glass and carbon fibers bonded with a polymer resin. The other, referred to as ACCR (Aluminum Conductor Composite Reinforced), is marketed by the 3M Corporation. Its core is comprised of ceramic fiber reinforced composite wires.

Q. What is the status of the ACCC product?

A. This product is still in the relatively early stages of development. We are not aware of any significant installations of ACCC and understand that installation of the first test line is in progress. One of the manufacturer’s claims, that of reduced electromagnetic fields compared to ACSR, appears to defy the basic laws of physics. This raises questions of credibility with respect to other claims associated with this product. We are skeptical of this product and discourage its application in the NRP.

Q. What is the status of the ACCR product?

A. ACCR is more developed than ACCC, and 3M Corporation claims that a full line of hardware is available for use with ACCR. However, to date, there have been only five trial installations of ACCR by utilities. These trials are in various stages of completion. Further, the cost per unit length of ACCR is expected to be on the order of 10 times that of ACSR, and there is only one supplier. Due to the high cost and relative lack of product experience, we recommend caution regarding application of ACCR to the NRP. If considered at all, we recommend that ACCR be used only for relatively short line sections and only after due consideration to the use of other alternative conductors, as discussed below.

Q. Are you aware of other conductors types, the use of which could reduce pole heights?

A. Yes, we are aware of Aluminum Conductor Steel Supported (ACSS) conductors. With ACSS, a stranded steel core provides most of the conductor's tensile strength. At high temperatures, the steel core supports the conductor entirely. The conductor's thermal expansion is that of steel which is significantly less than the thermal expansion of the aluminum/steel combination of ACSR.[6] While the thermal expansion of ACSS is greater than that of composite conductors, the use of ACSS achieves most of the high temperature sag reduction possible with composite conductors without the higher cost and risks associated with a new product.

Q. What is the status of the ACSS product?

A. This product has been available for some 35 years and has a wide installation base. It is available from three suppliers and its cost is estimated to be approximately 15% higher than ACSR.

[6]With ACSR, the steel core strands only help to support the conductor with a significant portion of the conductor's strength dependent on the aluminum strands. Therefore, with ACSR, the relatively high thermal expansion of the aluminum plays a major role in the increase in sag with increased loading.

Q. Beyond the cost premium, are there other disadvantages to ACSS?

A. ACSS conductor has a lower tensile breaking strength than an equivalent ACSR conductor. This raises a concern given the ice loading requirements for conductors in Vermont. There are various ways to mitigate this impact of ice loading, including reduced span lengths and the use of a variation of ACSS, discussed below.

Q. What is the variation of ACSS that may alleviate the concern with ice loading?

A. A variation of ACSS, referred to as ACSS/TR, utilizes aluminum strands with trapezoidal cross sections which reduce the outside diameter of the wire for a given net cross sectional aluminum area. For a given outside diameter, ACSS/TR has a higher tensile strength and lower electrical resistance (resulting in lower losses) than ACSR. ACSS/TR comes at an additional cost premium on the order of 25% over ACSR.

Q. What is your overall recommendation regarding consideration of alternative conductors for the NRP?

A. We recommend that ACSS and ACSS/TR, for reasons including cost, number of suppliers and product maturity, be considered for situations in which pole height reductions are desirable. Before application, careful consideration should be given to the specific requirements of a given line segment.

Q. Does this conclude your testimony?

A. Yes.